CONVENTIONAL AND SOLID STATE SPEED CONTROL OF AC DRIVES

conventional speed control of AC Drives :-

The speed of induction motor can be controlled by two methods. are
(1) Stator side control
(2) Rotor side control

Types of stator side control:

(i) Stator voltage control
(ii) stator frequency control.
(iii) voltage/frequency (v/f) control
(iv) Pole changing method.

Types of rotor side control:

(i) Adding external resistance in the rotor.
(ii) Cascade control.
(iii) Injecting EMF into rotor circuit (slip Power Recovery scheme)

Stator side control:-

(i) stator voltage control:-

The induction motor speed can be controlled by varying the stator voltage. This method of speed control is known as stator voltage control. Here the supply frequency is constant.

$\therefore T \propto V^2$.

The Torque is directly proportional to square of the supply voltage. Hence by varying supply voltage, the Torques and speed can by varied.

* This method, cheapest and easist, is rarely used because a large charge in voltage is required for a relatively small charge in speed. This large charge in voltage will result in a large charge in the flux density there by seriously disturbing the magnetic conditions of the applied frequency.

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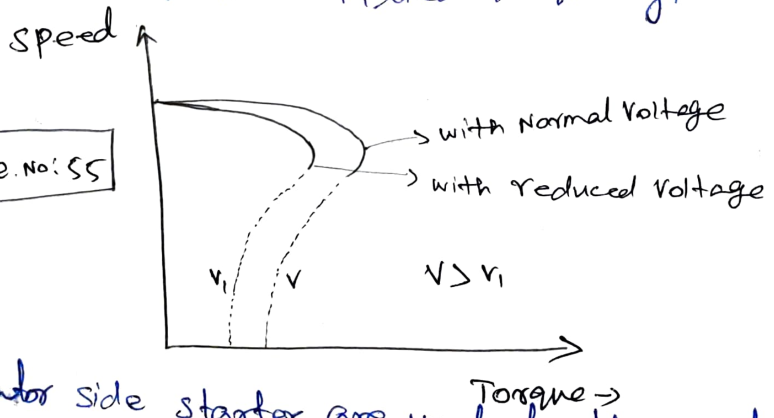

* stator side starter are used for this control.

(ii) stator frequency control:-

* The synchronous speed of induction Motor is $N_s = \frac{120f}{P}$.

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* The Actual speed N is slightly less than N_s, the speed of the motor can be varied by charging the supply frequency.

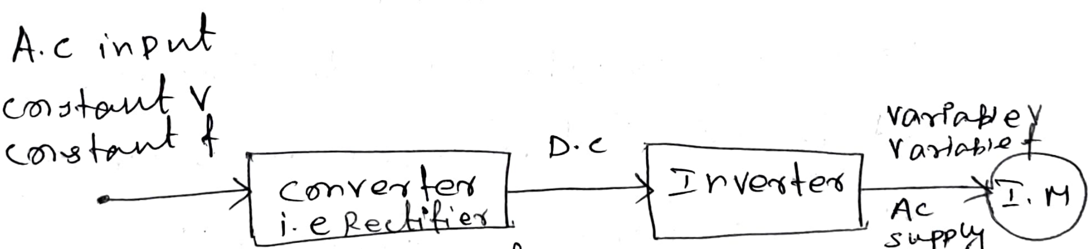
(iii) Voltage/frequency method (or) V/f method:-

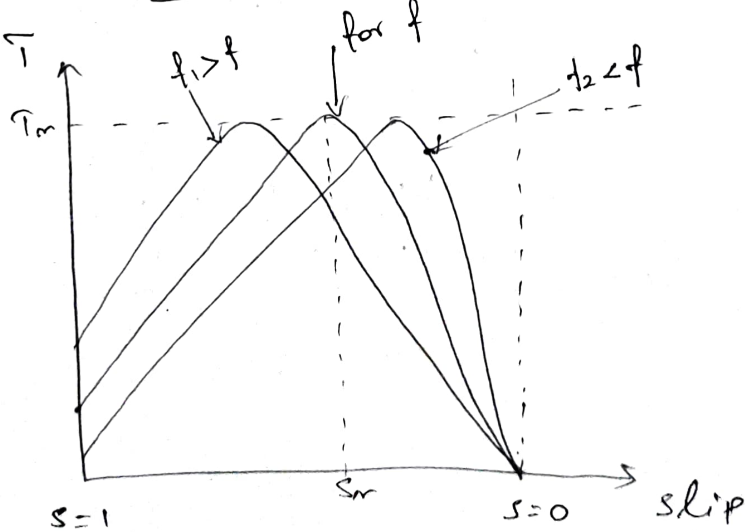
The air-gap flux is $\phi_g = \frac{1}{4.44 K_1 T_{ph_1}} \left(\frac{V}{f}\right)$

where

K_1 = Stator winding constant
T_{ph1} = stator turns per phase
V = supply voltage
f = supply frequency.

By varying the supply frequency, the air-gap flux changes. This will lead to saturation of the motor. To avoid this, the air-gap flux should be maintained constant. To maintain air-gap flux constant, 'V' and 'f' must be changed. It can be obtained by using power electronics converters. It is one of the most powerful method is which by varying V, f and maintaining (V/f) ratio constant, speed can be changed.





(iv) Pole changing Method:-

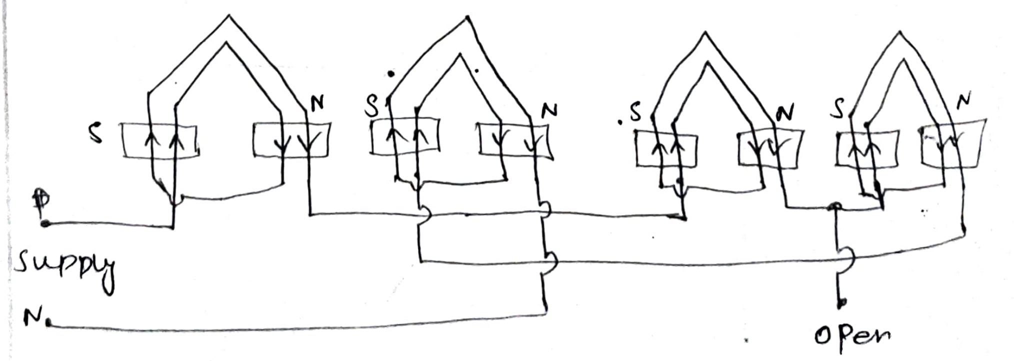
This method is easily applicable in squirrel cage motors because the squirrel cage rotor adapts itself to the no. of poles. From the speed equation $N_S = \frac{120f}{P}$, if the No. of poles in the stator changes then the speed can be changed.

The stator poles can be changed by

(a) consequent poles method
(b) multiple stator winding method
(c) Pole amplitude modulation method.

(a) consequent poles method:

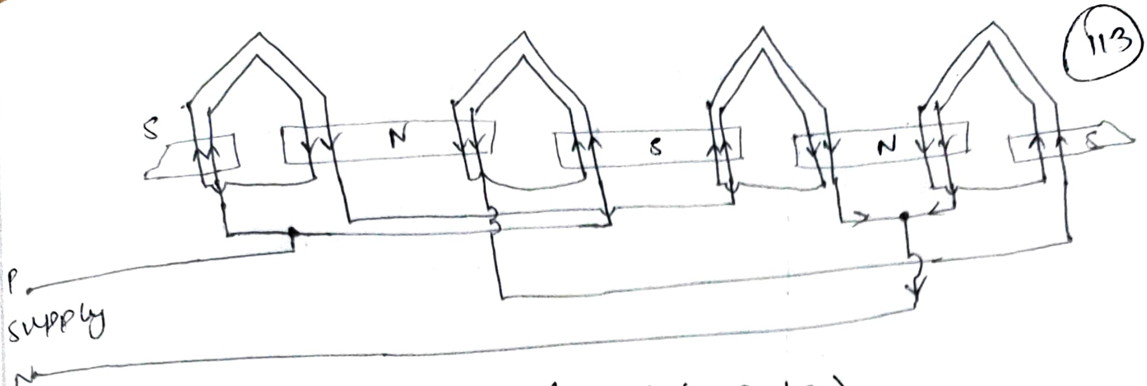
In this method, connections of the stator winding are changed with the help of simple switching. Due to this, the No. of stator poles get changed in the ratio 2:1. Hence either of the two synchronous speeds can be selected.



(a) Pole winding (8 pole)

$\therefore N_S = \frac{120f}{P} \Rightarrow \frac{120(50)}{8}$

N...



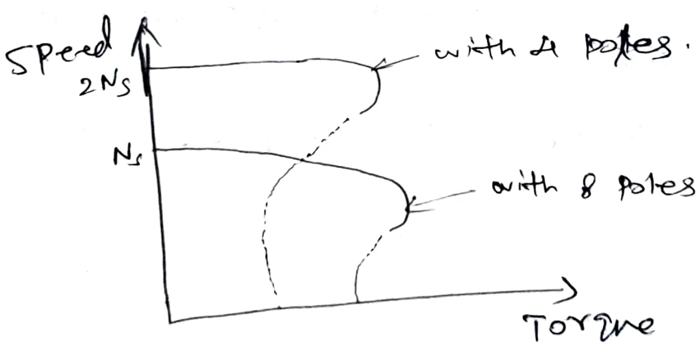
(b) Pole winding (4 Pole)

$N_s = \frac{120(50)}{4} \Rightarrow 1500 rpm.$

(b) multiple stator winding method:-

In this method instead of one winding, two separate stator windings are placed in the stator core. The windings are placed in the stator slots only but are electrically isolated from each other.

Thus giving supply to one of the two windings and using switching arrangement, two speeds can be achieved.



⇒ Rotor side methods:-

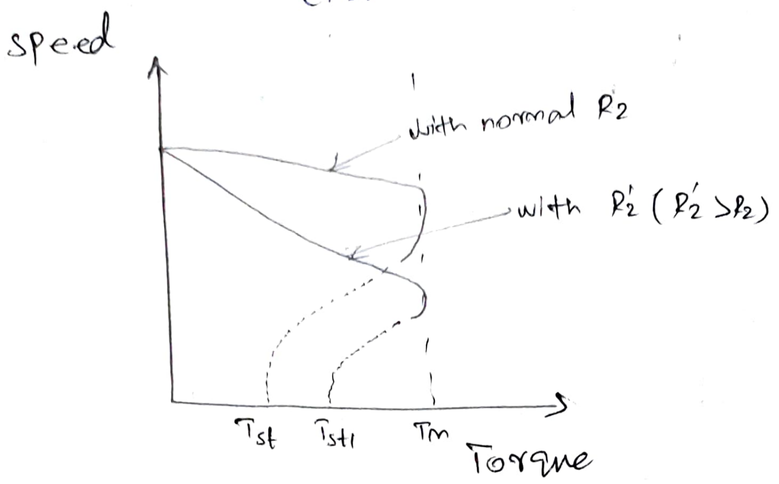
(a) Adding external Resistance in the Rotor circuit:-

W.K.T $T \propto \frac{sE_2^2 R_2}{R_2^2 + (sX_2)^2}$

For low slip region $(sX_2)^2 << R_2$ and can be neglected and for constant supply voltage E_2 is also constant.

(44)

$$T \propto \frac{sR_2}{(R_2)^2} \propto \frac{s}{R_2}.$$



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Disadvantages:-

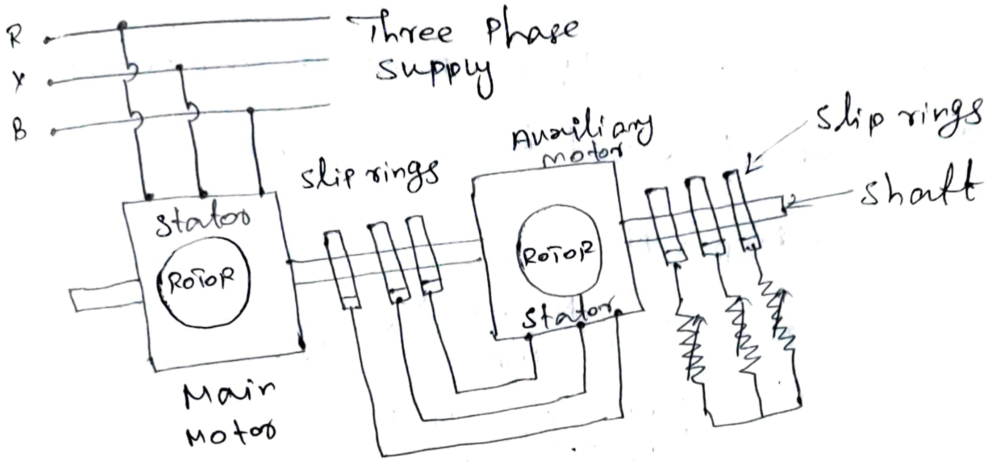
* large speed changes are not possible. because for large speed change, large resistance is required.
* It's not used for squirrel cage induction motors.
* Speed above the normal values can not be obtained.
* large power loss occurs due to I^2R loss.
* Efficiency is low.

(b) Cascade control:-

This method is also called concatenation (or) tandom operation. of the induction motors.

* In this method, two induction motors are mounted on the same shaft. one of the two motors must be of slip ring type which is called main motor.

* The second motor is called auxiliary motor. The auxiliary motor can be slip ring type (or) squirrel cage type.



The stator of the main motor is connected to the 3ϕ supply. while the supply of the auxiliary motor is derived at a slip frequency from the slip rings of the main motor. This is called cascading of the motors. If the torques produced by both act in the same direction, cascading is called cumulative cascading. If torques produced are in opposite direction, cascade is called differential cascading.

let, P_A = No. of Poles of main motor

P_B = No. of poles of auxiliary motor

f = supply frequency.

$$\therefore N_{SA} = \frac{120f}{P_A}$$

The speed N is same for both the motors as motors are mounted on the same shaft.

$$S_A = \frac{N_{SA} - N}{N_{SA}}$$

Now f_A = frequency of rotor induced EMF of motor A

$f_A = S_A \cdot f$ as $f_r = sf$.

The supply to motor B is at frequency f_A. i.e $f_B = f_r$

$$N_{SB} = \frac{120 f_B}{P_B} = \frac{120 f_A}{P_B} = \frac{120\, s_A . f}{P_B}$$

$$N_{SB} = \frac{120 (N_{SA} - N) f}{P_B \times N_{SA}}$$

Now on No load, the speed of the rotor B i.e N is almost equal to it's synchronous speed (N_{SB})

$$N_{SB} = N$$

$$N = 120 \left(\frac{N_{SA} - N}{N_{SA}} \right) \times \frac{f}{P_B}$$

$$= \frac{120 f}{P_B} \times \left(1 - \frac{N}{N_{SA}} \right)$$

$$= \frac{120 f}{P_B} \times \left(1 - \frac{N}{\left(\frac{120 f}{P_A} \right)} \right)$$

$$N = \frac{120 f}{P_B} \left[1 - \frac{N P_A}{120 f} \right]$$

$$\left[\because \frac{N}{120 f} = P_B \right] \quad (N = N_{SB})$$

$$\therefore \quad N \left[1 + \frac{P_A}{P_B} \right] = \frac{120 f}{P_B}$$

$$[1 - a]^{-1} = 1 + a$$

$$\boxed{N = \frac{120 f}{P_A + P_B}}$$

Thus in cascade control, four different speeds are

(a) w.r.t synchronous speed of A independently

$$N_S = \frac{120 f}{P_A}$$

(b) w.r.t synchronous speed of B independently with main motor is disconnected and B is directly connected to supply.

$$N_S = \frac{120 f}{P_B}$$

(c) Running set as cumulatively cascaded

$$N = \frac{120 f}{P_A + P_B}$$

(d) Running set as differentially cascaded

$$N = \frac{120f}{P_A - P_B}$$

Disadvantages:-

* It requires two motors which makes the set expensive.
* Smooth speed control is not possible.
* Operation is complicated
* The set cannot be operated if $P_A = P_B$.

(c) Slip power Recovery schemes:-

In this method, a voltage is injected in the rotor circuit. The frequency of rotor circuit is a slip frequency and hence the voltage to be injected must be at a slip frequency.

* It's possible that the injected voltage may oppose the rotor induced EMF or may assist the rotor induced EMF. It's in the phase opposition, effective rotor resistance increases. If it is in the phase of rotor induced EMF effective rotor resistance decreases. Thus by controlling the magnitude of the injected EMF rotor resistance and effectively speed can be controlled.

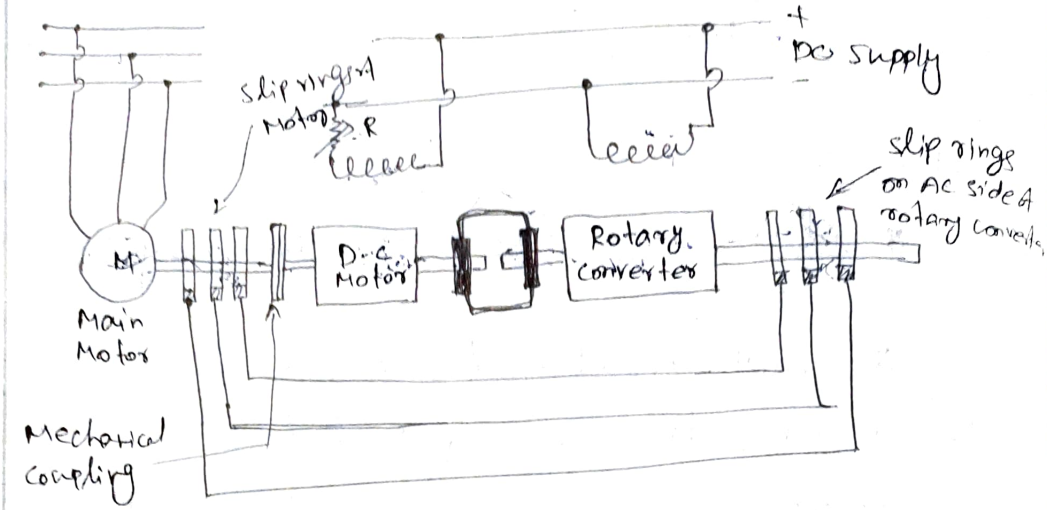
The Methods are

(i) Kramer system

(ii) Scherbius system.

(18)

(i) Kramer System:-



* It consists of main induction motor M, the speed of which is to be controlled. The two additional equipments are, D.C motor and a rotary converter. The slip rings of the main motor are connected to the AC side of a rotary converter. The D.C side of rotary converter feeds a DC shunt motor commutator which is directly connected to the shaft of the main motor.
* A separate DC supply is required to excite the field winding of DC motor and exciting winding of a rotary converter. The variable resistance is introduced in the field circuit of a DC motor which acts as a field regulator.
* The speed of the set is controlled by varying the field of the DC motor with the rheostat 'R'.

* When the field resistance is charged, the back EMF of motor changes. Thus the DC voltage at the commutator changes. This changes the DC Voltage on the DC side of a rotary converter.

* Now rotary converter has a fixed ratio between it's AC side and DC side voltages. Thus Voltage on its AC side also changes. This AC Voltage is given to the slip rings of the main motor. so the Voltage injected in the rotor of main motor changes which produces the required speed control.

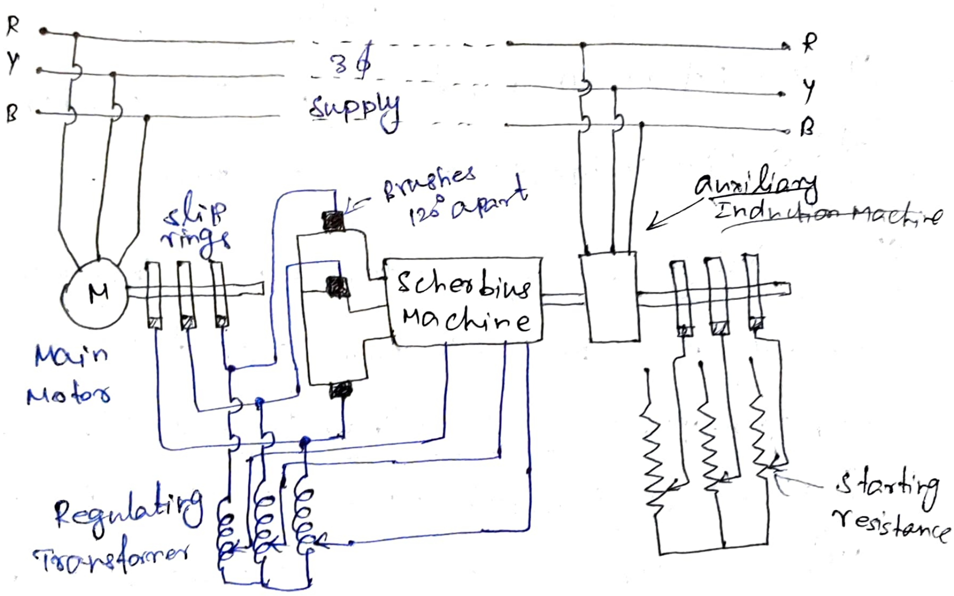
* Very large motors above 4.000 kW such as steel rolling mills use such type of speed control. The main advantage of this method is that a smooth speed control is possible. ||ly wide range of speed control is possible.

* Design of a rotary converter is practically independent of the speed control required.

* If rotary converter is over excited, it draws leading current and thus power factor improvement is also possible along with the necessary speed control.

(ii) Scherbius system:-

This method requires an auxiliary 3 phase (or) 6 phase AC commutator machine which is called scherbius machine. The difference between kramer system and this system is that the scherbius machine is not directly connected to the main motor, whose speed is to be controlled.



* The scherbius machine is excited at slip frequency from the rotor of a main motor through a regulating transformer. The taps on the regulating transformer can be varied, this changes the voltage developed in the rotor of scherbius machine, which is injected into the rotor of main motor. This controls the speed of the main motor.

The scherbius machine is connected directly to the induction motor supplied from main line so that it's speed deviates from a fixed value only to the extent of the slip of the auxiliary induction motor.

For any given setting of the regulating transformer, the speed of the main motor remains substantially constant irrespective of the load variations.

similar to the kramer system, this method is also used to control speed of large induction motors.

<u>Disadvantages:-</u>

* It's only used for slip ring induction Motors.